Windows

Introduction

Windows are essential to every home. They give a house character and bring a home alive by providing daylight and a view. They admit warm sunshine in winter and cool breezes in summer. Yet, for all their benefits, windows are a weak spot in the exterior shell. They can be a source of drafts and can become covered with condensation and ice on cold days. Windows may cause overheating and poor ventilation if they are the wrong size or in the wrong place.

Poor window performance wastes energy and increases space heating costs. Because window performance affects both indoor comfort and energy consumption, careful consideration must be given to window design, location and selection when planning a new home or renovating an existing one. This publication provides guidelines to assess windows and make good decisions.

Window Terminology

A number of window terms are used here (Figure 1).

Frame -- the casing of the window which holds the sash in place.

Glazing -- clear part of the window. Glass is a glazing, as are rigid and flexible plastics often used for interior storm windows.

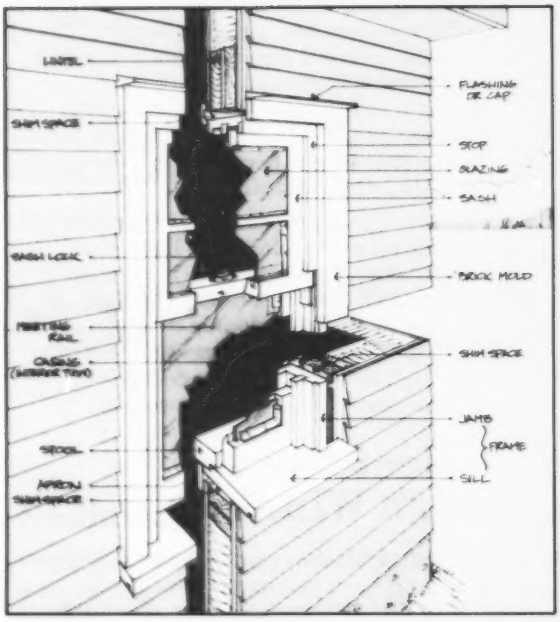


Figure 1

Rough Opening -- opening in the wall into which a window is placed. The rough opening width is the horizontal distance between the house framing studs on either side. The rough opening height is the vertical distance between the framing support above (lintel) and the framing support below.

Sash -- framework which holds a pane of glass.

Sealed Unit -- factory-assembled window unit with two or more layers of glazing sealed around the edges making it airtight. May be referred to as **insulating glass or thermopane unit.**

Storm Window -- layer of glazing added to the interior or exterior of an existing window.

Various styles of windows are available. Table 1 compares five common types: awning, casement, double hung, fixed and slider.

Three other window styles that you may consider for special purposes are:

- **Bay or Bow** -- This style is formed by a series of windows extending out from the wall. The bay window usually has three sections, the bow five. Set at various angles, the bay or bow window takes full advantage of light, ventilation and views. By alternating casement and fixed windows in the unit, all can be cleaned from the inside. Bay and bow windows are difficult to install and must be properly air sealed and insulated, especially in the floor overhang.
- **Patio Doors** -- There are two types. First, the typical friction fit type like a standard horizontal sliding window. Second, a new type with a fixed section and a sliding section. The fixed section pops out and glides on a wheeled rail. The friction fit type is difficult to weatherstrip tightly. The weatherstripping must be constantly maintained. The new type uses compressible weatherstripping which is easy to install and maintain.
- **Skylights** -- These are windows in the roof or ceiling which provide additional light and ventilation while maintaining privacy and wallspace. Skylights are available in fixed or operable styles and with double or triple glazing and should be used sparingly due to potential high heat loss and condensation. Get professional advice to avoid problems.

How Heat Moves Through Windows

Before you choose windows, understand how heat is transferred between indoor and outdoor environments. **Heat transfer takes place when a temperature difference exists.** The transfer processes are conduction, convection, radiation and air leakage.

Conduction

Anyone who has gripped the handle of a hot metal frying pan has painfully experienced heat transfer by conduction. Although heat transfer can be rapid, **the ability of different materials to conduct heat varies greatly.** It is important, therefore, that windows are constructed of materials with low conduction rates.

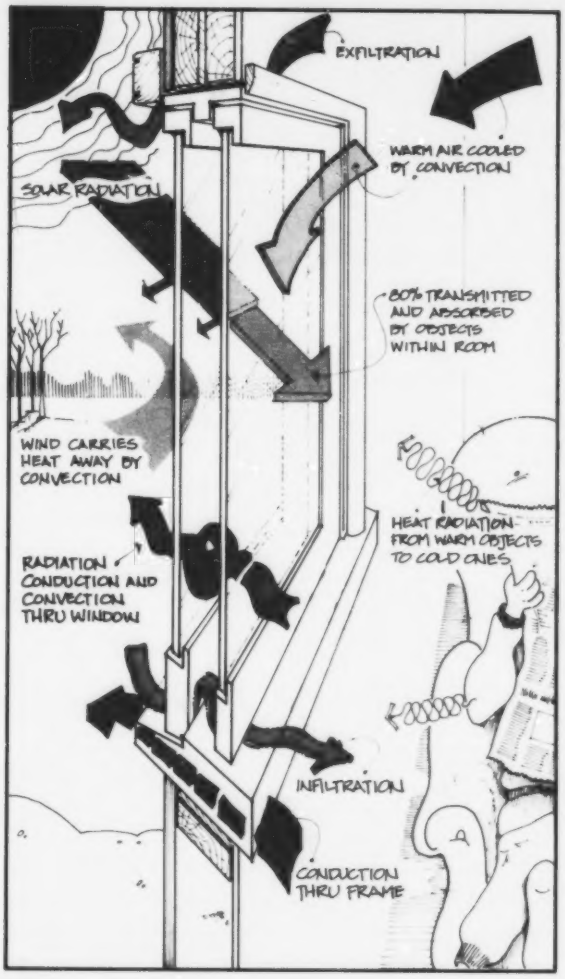

EXFILTRATION
WARM AIR COOLED BY CONVECTION
SOLAR RADIATION
80% TRANSMITTED AND ABSORBED BY OBJECTS WITHIN ROOM
WIND CARRIES HEAT AWAY BY CONVECTION
HEAT RADIATION FROM WARM OBJECTS TO COLD ONES
RADIATION CONDUCTION AND CONVECTION THRU WINDOW
INFILTRATION
CONDUCTION THRU FRAME

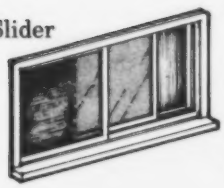
Figure 2

The paths for heat conduction through a window are the sash, the frame and the glazing (Figure 2). Choosing materials with low conduction rates for the frame and sash will reduce heat loss through this part of the window. Heat loss through the glazing is primarily affected by the amount of air trapped between the panes. Air is a poor conductor of heat. Conduction is slowed by layers of still air (called air films) along the inner and outer surfaces of each glazing and by the air trapped between each pane.

Materials that are **poor conductors** of heat are said to have a **high resistance** to heat flow. This thermal resistance is designated by the metric RSI-value (imperial R-value). Materials with higher RSI (R)-values are better insulators.

Table 1

Comparison of Common Window Styles

Window Style	Comments
Awning	• Will not allow rain penetration when open • Easy to weatherstrip • Combines with fixed unit for more energy efficient window • Provides up to 100 per cent ventilation through window area, but will not readily catch a breeze • Poor emergency exit when used in basement
Casement	• Directs breezes into a room • Easy to weatherstrip • Provides up to 100 per cent ventilation through window area • Size limited by strength of hardware • Generally most expensive • Can be damaged if open in high winds
Double Hung	• Most common in older homes • Provides ventilation through 50 per cent of window area • Generally high air leakage and frequent weatherstripping maintenance • No built-in screen • Can be difficult to clean especially with small panes • Meeting rail between sashes can obstruct view
Fixed	• Least air leakage • Accommodates large glass areas • No hardware or mechanism to fail • Provides maximum light and view • Most secure against forced entry but no emergency exit • No ventilation • Outer pane must be cleaned from outside
Slider 	• Includes horizontal and vertical units • Horizontal units allow ventilation and rain protection simultaneously • Easy to clean from inside if sashes removable • Normally least expensive of operable windows • Provides ventilation through 50 per cent of window area • Requires frequent weatherstripping maintenance • Generally least secure against forced entry

Convection

Convection is the movement of heat in liquids and gases due to temperature difference. Although air is a poor conductor it readily convects heat because warm air is light and tends to rise while cold air is heavy and sinks. As shown in Figure 2, convective heat loss from the window occurs in the following ways:

- Cold winter winds take heat away from the window surface by convection. Wind also reduces the window's overall thermal resistance (RSI (R)-value) by removing a large portion of the outside air film.
- Convection results in the formation of air currents inside as warm air next to the glass is cooled and sinks to the floor.
- Convection also occurs in the air space between glazings as the warm inner space loses heat to the cold outer pane. Convection increases with spaces larger than 19 mm (¾ inch).

Radiation

You are warmed by radiant energy transmitting from the fire when you are in front of a campfire or fireplace. The sun radiates energy (solar gain) in the form of visible light, shortwave infra-red radiation and, in smaller amounts, ultraviolet radiation. The amount of radiant energy transmitted to the house interior depends on the number of layers of glass. For each additional layer, solar gain is reduced by about 10 per cent (Figure 2). Each layer of low-e film also reduces the amount of radiation transmitted by about 10 per cent. Low-e (emissivity) windows have a thin, metallic coating applied to glass or a plastic film to increase the R-value of a window unit.

In a house, most transmitted solar energy is absorbed by room surfaces and re-radiated as longwave infra-red radiation. The part that is re-radiated back to the window surface is

absorbed almost entirely by the glass. Most of it, however, will be trapped indoors. If a room has a lot of glazing it can cause overheating even in the winter.

Air Leakage

Uncomfortable drafts in winter are caused not only by convection currents, but also by cold air leaking into the house (infiltration) as warm air leaks out (exfiltration) (Figure 2). This leakage is caused by a pressure difference between the inside of the house and the outdoors. This difference is caused by winds or household appliances that exhaust indoor air outside, such as furnaces or clothes dryers.

Air leakage occurs through ill-fitting, poorly weatherstripped and improperly installed windows (Figure 3). It can be detected by using a "draft indicator" such as the smoke column from an incense stick or smouldering cotton string.

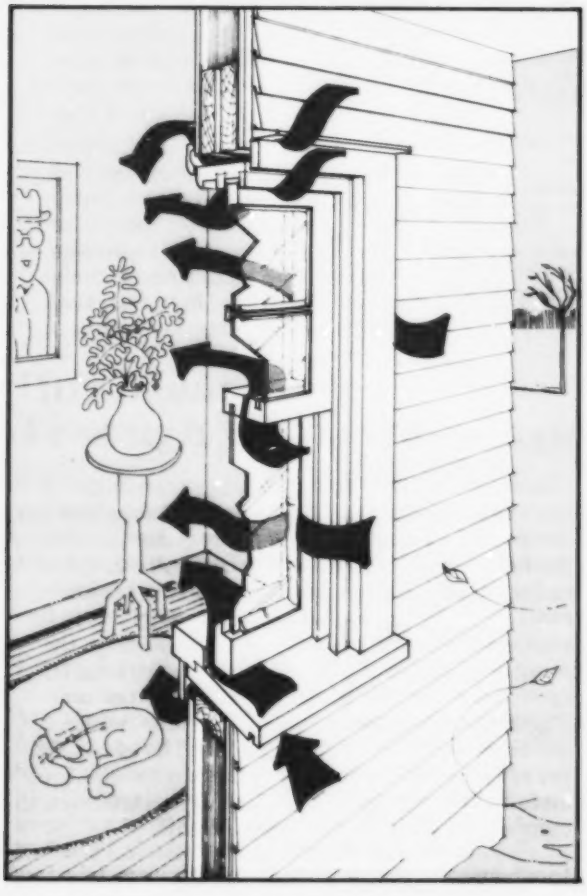


Figure 3

Assessing Your Windows

The first step in improving windows is to assess performance and identify problems. Table 2 lists some common problems and suggests causes and solutions.

Choosing a Plan of Action

Once window problems are identified, decide on methods to solve them. Options ranked in order of increasing cost and effort are:

- repair deteriorated windows
- caulk and weatherstrip
- install additional glazing such as storm windows or reglaze with thermal units
- install sun control devices such as solar films, awnings or tinted glass
- replace and modify existing windows

Repair Deteriorated Windows

It is usually less expensive and more convenient to repair windows than to replace them. Water damage causes most window deterioration. Before repairing windows, identify and eliminate any sources of moisture penetration. Examine the sill. It should slope away from the window to allow water to drain off. If the under side of the sill is flat, a drip groove may have to be cut to ensure proper runoff (Figure 4).

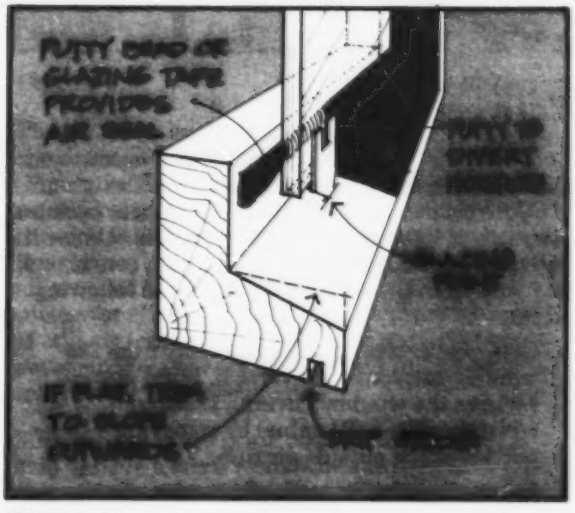


Figure 4

(continued page 6)

Table 2

Window Problems, Causes and Solutions

Indication	Possible Causes	Suggested Solutions
Water puddling on sill	• Sill does not slope away from window	• Cut or build slope into existing sill
Water runoff towards house on underside of sill	• Underside of sill is flat (not notched)	• Cut drip groove along underside to ensure proper runoff
Blistering, cracking, flaking and peeling paint	• Water penetration and moisture saturation • High indoor humidity	• Determine moisture source and eliminate if possible • Clean, dry and repaint affected area
Warping and rotting wood windows	• Moisture penetration of window parts due to deterioration of paint or caulking	• Repair damaged parts of window and repaint • Cover with aluminum or vinyl cladding • Replace with maintenance-free windows
Cracked, loose or missing glazing or glazing putty	• Putty has dried and weathered with age	• Reputty or reglaze window as necessary
Drafts	• Infiltration through and around window • Cold glass temperatures	• Provide good air seal around glass, weatherstrip and caulk (see *Caulking and Weatherstripping*) • Seal shim space between frame and rough opening • Reglaze existing sash with thermal unit • Install additional layers of glazing
Overheating	• Inadequate shading • Excessive glazing • Inadequate ventilation	• Install awnings, sun control films or tinted glazing • Eliminate or reduce window size • Replace window with unit that provides more ventilation • Install additional window or skylight
Inadequate natural lighting	• Insufficient or poorly positioned glazing	• Enlarge window opening • Install additional windows or skylight
Glare	• Too much glazing or unbalanced lighting	• Reduce glazing area or balance lighting by installing a window on adjoining wall or skylight
Condensation on inside surface of inner pane	• High indoor humidity combined with cold inner pane	• Reduce indoor humidity level • Install additional layer of glazing • Reglaze existing sash with thermal unit
Condensation between layers of glazing	• Air leakage into space between glazings • Broken seal	• Install additional layer of glazing • Install new thermal unit
Condensation on frames of aluminum or steel windows	• Cold metal frame inside due to excessive heat loss	• Reduce indoor humidity • Replace windows with units whose frames are made of less conductive materials
Condensation on specific windows only	• Refer to *Condensation Concerns* booklet for detailed description	• Refer to *Condensation Concerns* for detailed description

Examine for paint cracks and chips and check the wood for deterioration. If decay is not extensive, the area can be dried, treated with fungicide and repaired with putty. If deterioration is more serious, saving the window may be possible by using fungicide to stop decay and then cladding the surfaces with a material such as aluminum.

To repaint windows, start by removing the sash. Repair, caulk and weatherstrip the sash and the frame. Caulk the joint between the jamb and the sill to control water penetration. Remove excess layers of paint that make windows difficult to operate and repair or replace faulty hardware.

Before replacing broken glazing or installing new putty, remove existing putty, glazing points, glass and putty behind the glass. Reglaze the window as shown in Figure 4.

Lay a bead of putty to provide an air seal, press the pane of glass into place, insert glazing points to secure the glass and, finally, lay a bevelled layer of putty around the edge of the glass to seal against water penetration.

Repaint windows with good quality acrylic latex or alkyd (oil base) paint. Before painting new windows, apply a primer appropriate for the paint to be used. A penetrating, transparent stain could be used instead of the primer.

Caulk and Weatherstrip

Air sealing the windows can be inexpensive and easily done. The uses of sealing products are described in *Caulking and Weatherstripping*. A number of points it mentions are:

- For windows that have never been weatherstripped, a compressible weatherstripping such as tubular vinyl or closed cell foam provides a good, durable seal. Where possible, apply weatherstripping along the edge of the sash **as well as** along the jamb. This double weatherstripping ensures an excellent seal on windows that open.
- Metal and vinyl sliders usually have factory-installed pile weatherstripping. When it is worn out, new weatherstripping can usually be slid into the channel. Replacement pile weatherstripping with a vinyl strip is available and provides an improved seal.
- For wide gaps, ethafoam rope or weatherstripping tape can be applied in the fall and removed in the spring.
- Consider a permanent seal of caulking to windows that are not needed for ventilation. **Ensure they are not possible emergency exists.**
- Be sure the caulking is compatible with other materials you are using. Acid-based silicone, for example, cannot be painted.
- Install sash locks to seal the sash tightly against the weatherstripping.

A common air leakage pathway is the shim space between the window frame and rough opening. Methods of sealing are shown in Figure 5.

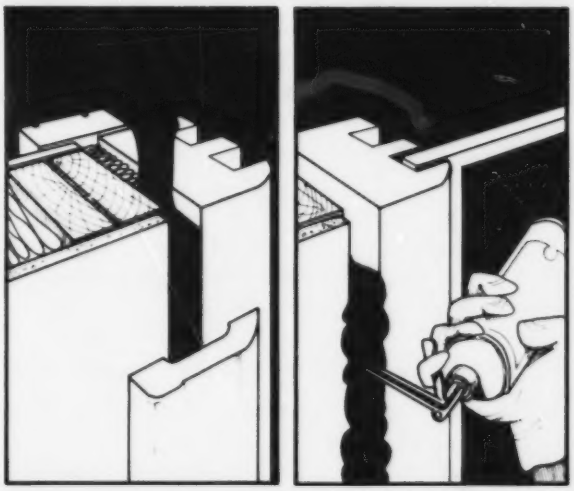


Figure 5

Polyurethane foams are most easily applied in cracks greater than 12 mm (½ inch) and provide a good seal with high thermal resistance. Some expand, however, and should be applied with caution or the window frame may warp. For smaller cracks, ethafoam cord and caulking is effective. The cord should be two times the diameter of the crack width to ensure a good fit.

Install Storm Windows

After windows are repaired and sealed to reduce air leakage, you may wish to increase indoor comfort and reduce heat loss by increasing their thermal resistance. Many add attic insulation to increase R-value and reduce heat loss through the ceiling. Conductive heat loss through a window can be reduced by increasing its R-value.

Adding a storm window is the most common way to reduce heat loss. It can be installed on the inside or outside of the window. An additional air space of at least 12 mm (one-half inch) will decrease the heat loss from a single-glazed window by approximately one-half. Remember, most of the increased thermal resistance comes from the air space created, and not from glazing. Benefits include reduced condensation and icing due to the increased temperature of the inner glazing.

Table 3
Commom Glazing Types

Glazing Type	Advantages	Disadvantages
Glass 3 mm (⅛ in.) (rigid)	• Readily available • Excellent transparency • Excellent durability • Non-combustible, chemically inert • Scratch resistant • Low IR transmittance[a] • Low thermal expansion/contraction	• Heavy • Low impact resistance • Breakage causes safety hazard • Careful installation required
Polyethylene 0.15 mm (6 mil) (flexible film)	• Readily available • Lightweight • Easy to cut • Inexpensive	• Short service life • Easily damaged • Poor visual appearance • High IR transmittance • Flammable
Vinyl 0.25 mm (10 mil) (flexible film)	• Lightweight • Easy to cut • High solar transmittance • Stronger than polyethylene	• Limited availability • Becomes brittle with age • Hard to eliminate wrinkles • Some visual distortion • High IR transmittance • Flammable
Vinyl-UV treated[b] 0.25 mm (10 mil) (flexible film)	• Resistance to UV degradation • Does not become brittle	• Similar to untreated vinyl but does not get brittle
Acrylic 3 mm (⅛ in.) (rigid)	• Readily available • Lightweight • Good durability • Moderate impact resistance • Fairly easy to cut • Low IR transmittance	• Incompatible with butyl tapes and sealants • Susceptible to scratches • Softens under moderate heat • High thermal expansion/contraction • Flammable
Polycarbonate 3 mm (⅛ in.) (rigid)	• High impact resistance • Lightweight • Good durability, transparency • Low IR transmittance • Available with scratch resistance surface	• Limited distribution • High thermal expansion/contraction • Flammable • Expensive

[a] Does not readily transmit infra-red radiation
[b] Exposure to ultraviolet radiation can break down some plastics over time

Properly installed, storm windows also reduce air leakage. Although both permanent and storm windows should be well sealed, **it is important that the inner layer of glazing is sealed tighter than the outer.** This prevents warm, moist air from leaking between glazings and condensing on the inner surface of the outer glazing.

Table 3 compares common glazing materials. Glass is the most widely used and its optical and thermal properties are the basis for comparison. If a glazing that is stronger, lighter or easier to cut than glass is required, plastic may be more suitable. The choice should be based on cost and function as thermal performance does not vary significantly.

There are systems available for attaching glazing materials to the windows. The most common are shown in Figure 6.

- **Magnetic Seal and Rigid Acrylic** -- Although more expensive, this method of installing rigid plastic ensures a good air seal. High thermal expansion and contraction rates of plastic may cause the magnetic seal to slide and the acrylic glazing to fall. Install a few retainer clips if this happens. This too will make the glazing more difficult to remove in an emergency.
- **Heat Shrink Film and Double-Sided Tape** -- This is the least expensive and provides an excellent seal. When the film is in place, heating it with a hair dryer tightens it across the opening. It is generally not reusable. Removing the tape often removes paint.

Interior application is preferable to reduce air leakage and increase durability. A tight seal to the inside will reduce condensation between glazing layers. If a room needs ventilation or an emergency exit, be sure interior storms can be easily removed.

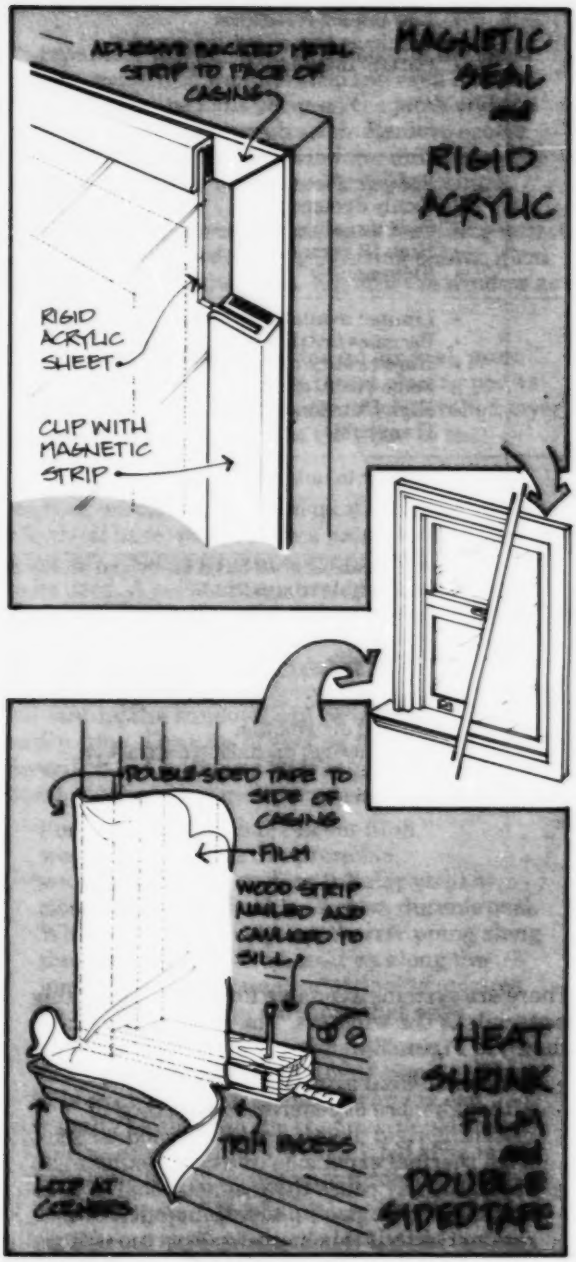

MAGNETIC SEAL and RIGID ACRYLIC
RIGID ACRYLIC SHEET
CLIP WITH MAGNETIC STRIP
DOUBLE-SIDED TAPE TO SIDE OF CASING
FILM
WOOD STRIP NAILED AND CAULKED TO SILL
HEAT SHRINK FILM and DOUBLE SIDED TAPE

Figure 6

Exterior storm windows of wood or metal can also be installed but this is an expensive alternative. A variety of units are available, including permanent or removable. Their main function should be to improve the thermal resistance of windows and not to stop air leakage. The principle air seal should still be provided by the inside window.

Consider ventilation requirements, the need for emergency exists, maintenance and appearance when choosing exterior storms.

Upgrade Window Glazing

Another way to increase thermal resistance is to replace existing glazing with sealed multi-glazed units. Whether or not this can be done depends on the design, material and condition of the existing sash and frame. If the window cannot accommodate a sealed unit with an air space of at least 12 mm (½ inch) between glazings, it may be more efficient and less expensive to install a storm window.

Consider hiring a qualified contractor because improper installation will void the manufacturer's warranty. If you do the conversion yourself, get proper installation information from the glass supplier. Allowance for expansion must be provided.

Sun Control

Rooms with large window areas facing east, south or west can get too much sun resulting in overheating, glare and fading of furniture.

Drapes and blinds block incoming sunshine, but obscure vision and reduce light. It is preferable to stop sunlight before it passes through the window. Shading with trees, overhangs, awnings or shutters can provide adequate sun control. Indoor "solar films" applied to the inside face of the glass are an alternate solution.

Solar films block sunlight. They are available in a variety of colors, each with a different sun-screening capability. Solar films also reduce the ability of glass to emit radiant energy absorbed by the glass. This causes the glass to heat up and expand. If the appropriate film is not applied, larger windows may expand too much and crack. If this occurs with sealed units, the manufacturer's warranty will be void. The application of solar films is best handled by an experienced contractor.

Once installed solar films are not easily removed and should be considered permanent. They do scratch and care must be taken when cleaning the window.

An alternative is to install tinted glass. This is an expensive option but will avoid the problems of solar films.

Replace Windows

If none of the previous methods adequately solves your particular window concerns, the only alternative may be to replace them.

If yours is an older home, window sizes may no longer be standard. Don't despair! This is not a major renovation. Many manufacturers custom build windows to your specifications.

Replacement units can be made to fit existing window frames (Figure 7). If you do the work yourself, proper installation is extremely important to ensure good window performance.

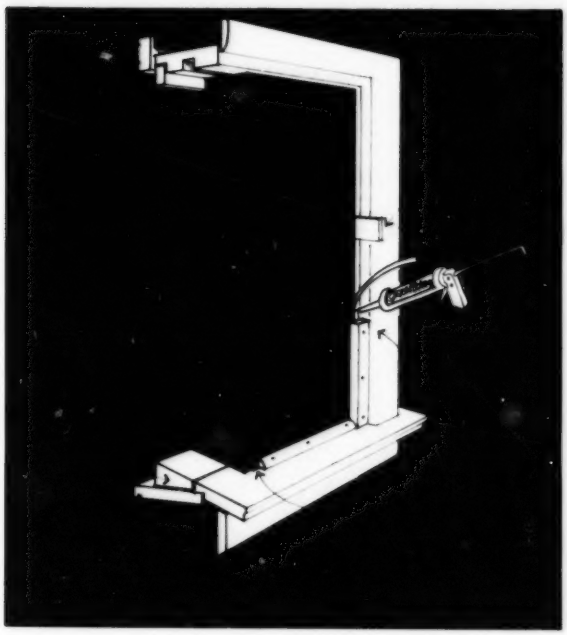


Figure 7

To operate properly, the window must be installed plumb, level and square (Figure 8). Ensure flashings are installed and the frame is adequately supported. The shim space between the frame and rough opening must be insulated and sealed to reduce heat loss and air leakage. The methods in Figure 5 will provide a good air seal.

Figure 8

If windows must be replaced, it provides a good opportunity to consider enlarging a window, eliminating a window, or creating a new opening. This usually involves a major renovation, but it may be the proper solution to inadequate ventilation, overheating, poor lighting or glare.

Selecting a New Window

In recent years window manufacturers have met the challenge to produce well-designed, long-lasting, energy efficient windows that require little maintenance.

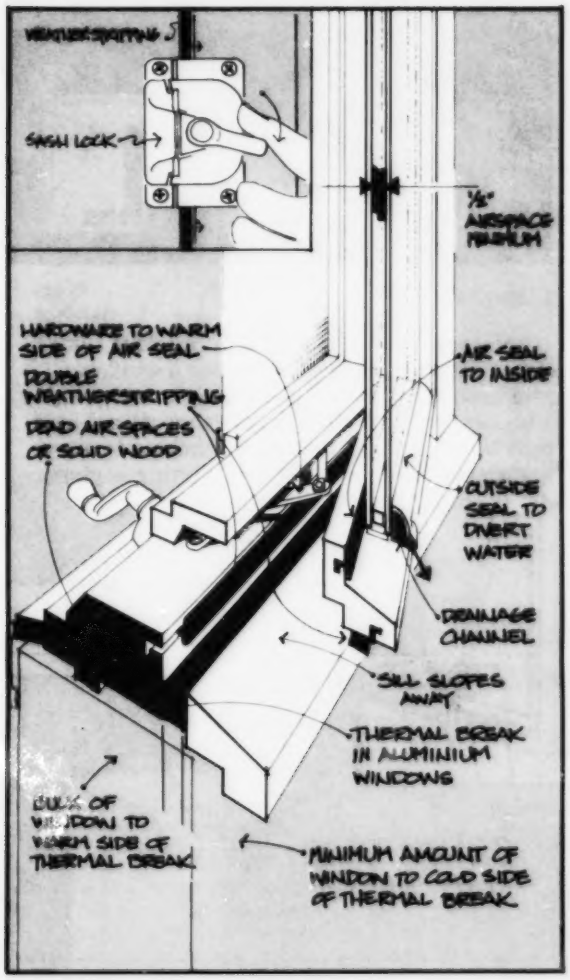

SASH LOCK
HARDWARE TO WARM SIDE OF AIR SEAL
DOUBLE WEATHERSTRIPPING
DEAD AIR SPACES OR SOLID WOOD
AIR SEAL TO INSIDE
OUTSIDE SEAL TO DIVERT WATER
DRAINAGE CHANNEL
SILL SLOPES AWAY
THERMAL BREAK IN ALUMINIUM WINDOWS
MINIMUM AMOUNT OF WINDOW TO COLD SIDE OF THERMAL BREAK

Figure 9

This section will help in the selection of an energy-efficient window that:

- reduces heat loss from the house
- prevents cold winter drafts
- reduces condensation and frost
- provides maximum light without overheating or glare
- provides adequate ventilation

Before selecting new windows, review Table 1 to determine the style you want. Figure 9 shows window features to consider. Choose a window with as many of these features as possible. Also obtain information obtain from the Canada Mortgage and Housing Corporation (CMHC) window evaluation reports, available from window manufacturers. The reports include information or air leakage test results and installation methods. Determine color and maintenance requirements. Measure the rough opening of the windows to be replaced and write the measurements down as width times height.

The features in Figure 9 can be found in windows made of wood, metal, fibreglass and a plastic called polyvinyl chloride (PVC). Wood is the best natural insulator. It is difficult to maintain and unless it is clad with aluminum or vinyl will need to be painted every four or five years. The window may be clad completely or weather-protected on the outside only, retaining the natural wood inside.

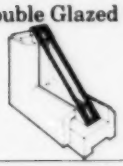
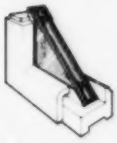
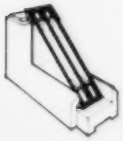
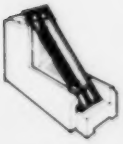
Metal windows are poor insulators and require a thermal break such as plastic or rubber (Figure 9) to slow down the movement of heat to the outside and help prevent condensation on the sash and frame. Metal windows are usually coated with a baked-on enamel and require little maintenance.

Vinyl and fibreglass windows, like wood, are poor conductors of heat and do not require a thermal break. They are virtually maintenance-free and impact and scratch resistant. Few colors are available. They can not be repainted.

Table 4 compares available products.

Table 4

Selecting a Glazing

Glazing Type	Comments
Double Glazed 	• RSI 0.36 (R 2.0) with a 12 mm (½ in.) air space • About one-half the heat loss of single glazed • No condensation down to -25°C with 30% indoor humidity levels
Double Glazed Low Emissivity (Low-e) Coating	• RSI 0.56 (R 3.2) with 12 mm (½ in.) air space • Admits less light than triple glazed, amount depends on type of coating • Advantages of triple glazed without the bulk and weight • Not visible
Double Glazed Low-e, Argon Gas 	• RSI 0.70 (R 4.0) with a 12 mm (½ in.) air space • Admits same light as low-e • Not visible
Triple Glazed (all glass) 	• RSI 0.56 (R 3.2) with a 12 mm (½ in.) air space • No condensation down to -40°C with 30% indoor humidity levels • Lets in about 10% less light than double glazed • Reduces outdoor noise • Bulkier than double glazed • Extra weight strains hardware designed for double glazed unit • More energy efficient than double pane in all orientations
Triple Glazed (2 glass, 1 suspended film) 	• Two types of film available • Type 1: RSI-value similar to triple glazed; maximizes visible light and solar gain, less effective in reflecting thermal radiation • Type 2: RSI 0.76 (R 4.3) with a 12 mm (½ in.) air space; less efficient in transmitting visible light but reduces winter losses and summer gains by reflecting thermal radiation • Bulk of triple glazed but weight of double glazed • Not Visible

Note: All RSI-values represent the center of the glazing. These values will vary with the type of spacer and frame used.. Check manufacturer's literature for RSI-values of specific window units.

New Developments

Various research agencies and companies are working to improve the thermal resistance of windows to values as high as RSI 1.8 (R 10) within the next decade. Three recent developments are **low-e units, insulated spacers** and **gas-filled sealed units.**

Low-e or low emissivity is a thin, metallic coating applied to glass or plastic film to increase the R-value of a window unit. The coating allows light to pass through but prevents the outflow of heat radiation. When applied on the outer surface of the inner pane of a double glazed window it raises the RSI value to 0.53 (R 3), similar to triple glazing. There is a reduction of eight per cent or more of the light admitted compared to triple glazing. Low-e is used as an alternative to triple glazing with its advantages of higher R-value and reduced condensation but without the bulk and weight.

Traditionally, metal spacers have been used to separate the panes of glass in a sealed unit. Metal conducts heat and due to this traditional sealed units lose a lot of heat around the edges. This results in condensation and icing during cold spells. New materials such as butyl-metal and silicone foam are being used as spacers to reduce this "edge effect".

To increase the insulation value of a sealed unit, some manufacturers use inert gases such as argon rather than air. Using gases only makes sense in windows that have reduced radiant heat losses such as low-e windows. These gases slow the conduction and convection heat losses through the window giving the units higher insulation value.

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